Ph.D. Title Proposal

on

Human Identification Using Dental X-Rays: A Deep Learning Framework Tailored for India

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Sr. no.	**Content**	**Page no.**
1	Introduction	1
2	Literature Review	5
3	Research Gap	7
4	Problem Statement	7
5	Objectives of Study	7
6	Research Hypotheses	7
7	Research Methodology	8
8	Statistical Plan	10
9	Expected Outcomes of the Study	10
10	References	10

Statement by the Candidate

I wish to state that the work embodied in this synopsis titled "Human Identification Using Dental X-Rays: A Deep Learning Framework Tailored for India" forms my own contribution to the work carried out under the guidance of Dr. Nilakshi S. Jain at the Shah and Anchor Kutchhi Engineering College. I declare that this written submission represents my ideas in my own words and where others ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission.

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1. Introduction

Disasters, whether natural or man-made, present significant challenges to societies by causing immediate loss of life and property and triggering long-term social, economic, and environmental impacts. Catastrophic events such as earthquakes, tsunamis, floods, fires, and terrorist attacks often result in mass casualties, leaving communities devastated and the identification of victims a critical task. This process is essential not only for legal purposes but also for providing closure to families who have lost their loved ones. However, traditional methods of identification, including fingerprint analysis, facial recognition, and DNA testing, often become ineffective in mass casualty scenarios where bodies are severely damaged or decomposed. In 2001, a devastating earthquake struck Gujarat, resulting in approximately 20,000 deaths. A novel virus known as the coronavirus was first detected in Wuhan, China, in December 2019 and has since caused nearly a million deaths[1]. In 2020, desert locust swarms ravaged parts of Asia, consuming crops within seconds and resulting in severe agricultural losses across several Indian states, including Gujarat, Rajasthan, Uttar Pradesh, and Madhya Pradesh. In 2010, Haiti experienced a devastating earthquake measuring 7.0 in magnitude, leading to approximately 230,000 fatalities. Another major disaster, the Indian Ocean tsunami in December 2004, claimed around 275,000 lives, making it one of the deadliest recorded events, impacting 14 countries, including India [2]. The September 11, 2001 attacks on the United State resulted in the deaths of 2,977 people, with over 25,000 others injured and many suffering long-term health issues. The following table presents the casualties that occurred in various states in India over different years.

Table 1: Major flood evens of last few years [3]

State	Year	Death	Population Affected
Assam	2012	20	Over 2 Million
Uttarakhand	2013	4100	Nearly 4000 villages
Madhya Pradesh	2013	30	40000 people
Jammu	2013	29	2600 villages
West Bengal	2015	48	10,000 villages
Tamil Nadu	2015	500	1.8 million
Gujarat	2017	224	0.3 million
Bihar	2017	253	180,000 people in 10 districts
Kerala	2018	339	5.4 million

The following figure represents the number of deaths due to natural disasters in India from FY 2008 to FY 2023.

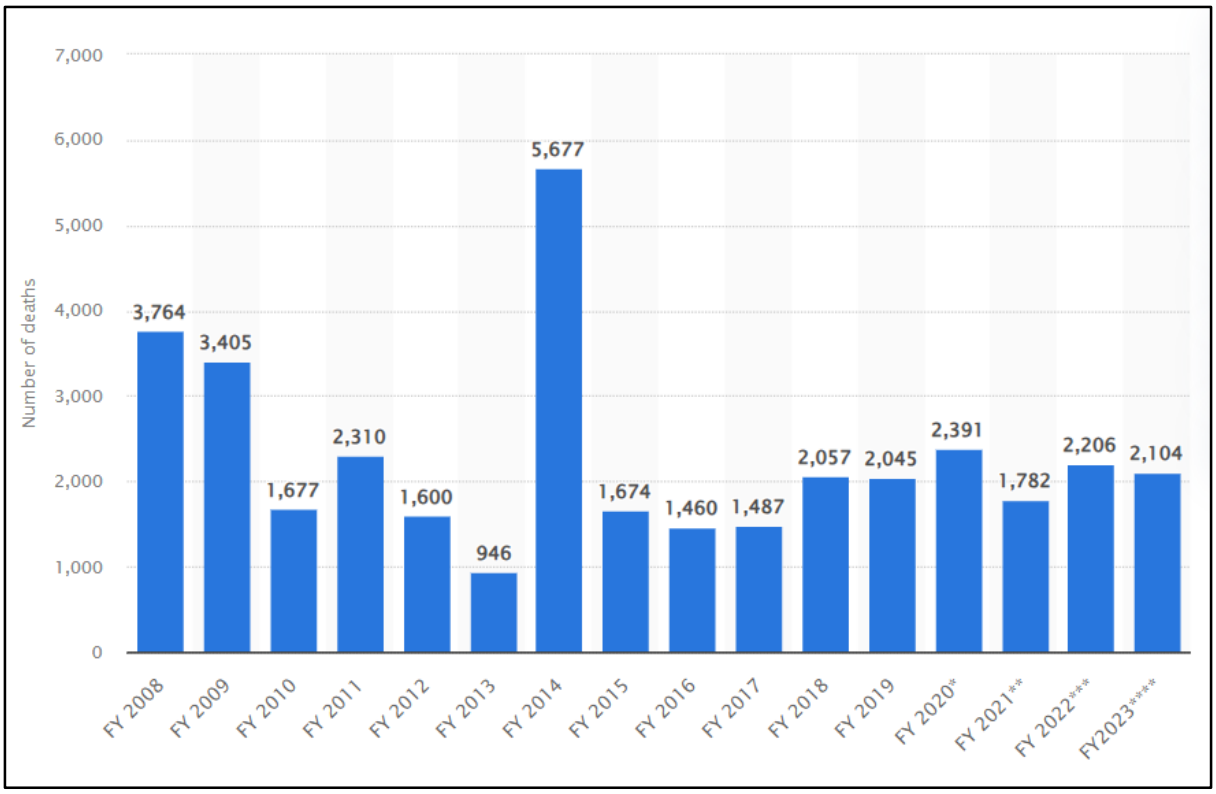

Figure 1: Number of deaths due to natural disasters in India

(https://www.statista.com/statistics/1007056/india-number-of-deaths-due-to-natural-disasters/ Release date June 2024)

In such situations, the identification of deceased individuals is important for both legal and humane reasons. Different approaches used for identification are use of fingerprints**,** DNA analysis**,** forensic facial reconstruction**,** biometric identification. In such extreme conditions, where traditional methods like fingerprints, DNA analysis, and facial reconstruction may be unavailable or compromised, the use of dental X-rays becomes an invaluable tool for identification due to their unique, durable, and consistent features [4]**.** The importance of dental biometrics has been demonstrated in numerous disasters. For instance, the 2004 Indian Ocean Tsunami highlighted the role of dental records in identifying victims when other methods failed due to the extent of decomposition and damage is shown in Figure 2.

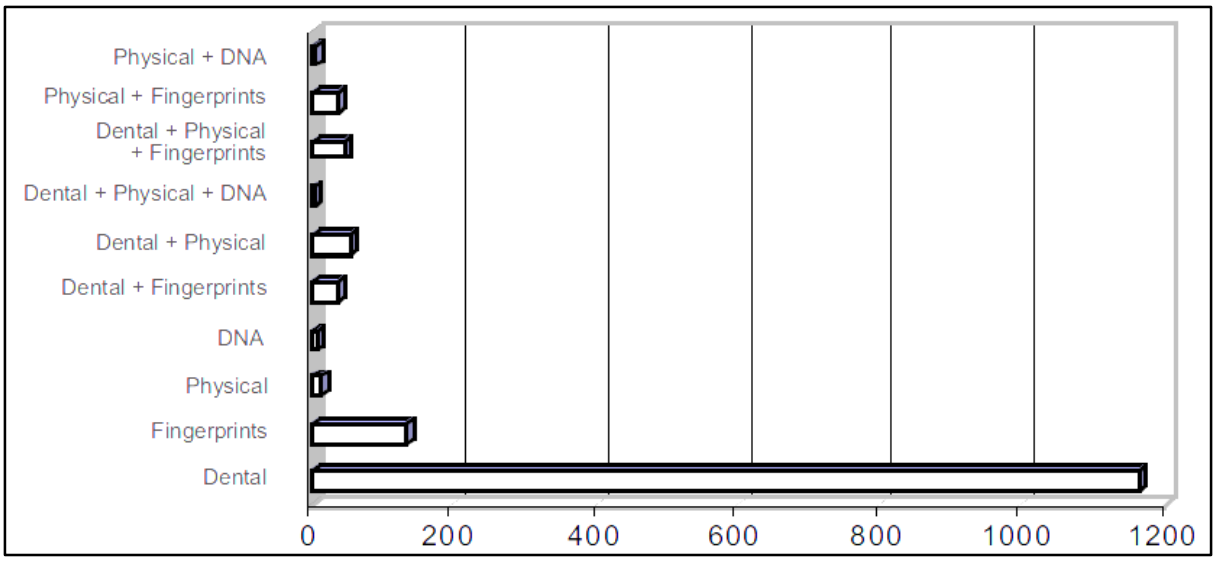

Figure 2: Number of victims identified [5]

Similarly, in the Great East Japan Earthquake and Tsunami on March 11, 2011 disaster dental identification was effective compared with fingerprint/palmprint identification and DNA-based identification. In Haiti Earthquake the identification of the deceased was done through comparison of dental records, DNA analysis and fingerprint records Also in September 11 attacks, dental records played a crucial role in identifying victims whose bodies were severely damaged by the impact of the attack. These examples specify the necessity of developing robust and efficient methods for utilizing dental evidence in disaster victim identification (DVI) [6][7].

Forensic Odontology: The Role of Teeth in Identification

Forensic Odontology, or forensic dentistry, applies dental knowledge to legal and investigative matters, particularly for identifying victims in mass disasters [8]. Teeth are the hardest part of the human body and can survive extreme conditions like high heat and trauma. As a result, they are often the only usable biometric for identifying individuals in situations where other forms of identification such as fingerprints or DNA are no longer available. A process in forensic odontology, involves comparing ante-mortem dental records (AM records) with post-mortem dental records (PM records). The AM records are obtained from dental exams taken during a person's lifetime, while the PM records are derived from dental X-rays and other imaging taken after death. Forensic odonatologists manually compare these records to establish a positive identification. The manual process of comparing dental records is time consuming and can sometimes result in inaccuracies. The forensic dentists not only help in identifying the victim but also they can identify the age, gender and socio-economic status [4].

The integration of artificial intelligence (AI) technologies, particularly machine learning (ML) and deep learning (DL) [9], has further revolutionized the field of dental biometrics. Traditional methods of analysing dental radiographs often involved manual comparisons, which were time-consuming and prone to human error. AI-based techniques have introduced automation to this process, significantly enhancing the speed, accuracy, and efficiency of victim identification. By automating the analysis of dental radiographs and eliminating the need

for manual intervention, AI has the potential to accelerate identification efforts, especially in large-scale disasters where time is critical. Dental imaging plays an important role in forensic odontology. Techniques like intra-oral and extra-oral X-rays help forensic experts to see and record detailed images of teeth and their structures. The categories of intraoral and extraoral x-rays are as mentioned in Fig. 2. Intra-oral X-rays involves placing an X-ray film inside the mouth to capture detailed images of the teeth and surrounding structures while extra-oral X-rays, such as panoramic X-rays, involves taking X-ray images from outside the mouth that show the entire dental structure in one image. Panoramic X-rays are useful in emergencies or disasters because they quickly capture a wide view of dental features, making it easier to match them with dental records from before the incident [10].

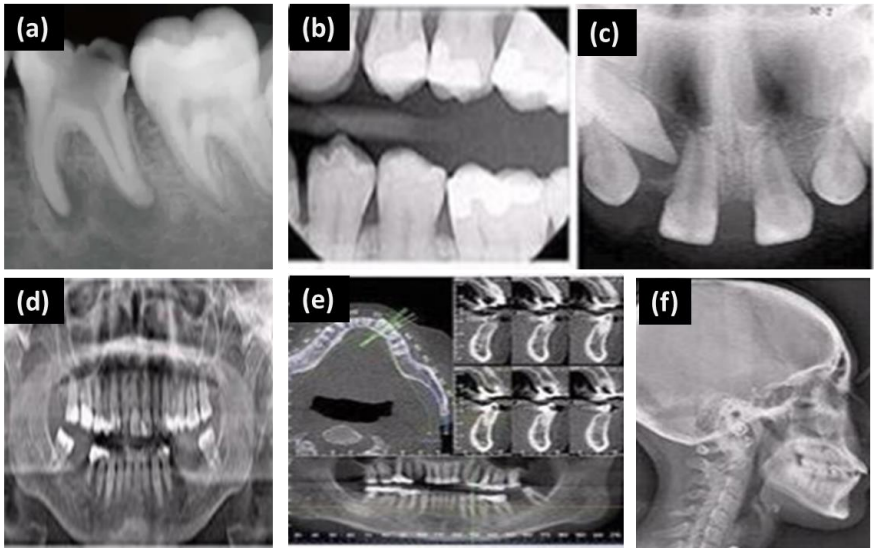

Figure 3: Categories of intraoral and extra oral X rays (a) Periapical X-ray, (b) Bite-wing x-ray, (c) Occlusal X-ray, (d) Panoramic x-ray, (e) CBCT X ray, (f) Cephalometric X-ray [10].

Human identification using dental X-rays typically involves three steps: segmenting the dental image, extracting tooth contours, and matching AM and PM radiographs. Many literature has focused on image segmentation methods to isolate tooth from the dental radiographs which is time-consuming and inefficient for large datasets. With the advancement in the field of computer science, machine learning and deep learning plays a vital role in medical image analysis. With deep learning techniques, there is no need for separate segmentation and contour extraction phase in dental identification; instead classification could be performed to identify the teeth directly. This automated approach reduces the workload for forensic experts and ensures consistency in the identification process. Unlike traditional machine learning models, which require manual feature extraction, deep learning systems can learn directly from raw data, making them more effective in handling complex datasets recorded in disaster scenarios. These advantages of deep learning influenced the use of deep learning for this research.

2. Literature Review

Below is a compilation of existing research focused on human identification

- Sagar V. Joshi et al.(2020), focused on identifying missing and unidentified individuals using dental panoramic radiographs. Their aims were to automate the process by analysing complex Dual Cross Pattern features that are challenging to assess visually. They evaluated four classifiers Feedforward Neural Network (FNN), Multiclass Support Vector Machine (m-SVM), k-Nearest Neighbor (k-NN), and Classification Tree (CT) to determine the most effective one based on retrieval accuracy. For the study a dataset of 10 adult subjects and 100 panoramic radiographs were used. Preliminary findings on this small dataset showed promising results .
- Bheemavarapu Naveen Kumar Reddy et al.(2022), highlighted the different radiographic techniques and procedures and its application in forensic odontology. They have specified that Imaging technologies and radiographs have become a vital component of modern medical practice and forensic odontology. Odonatological method for human identification is used commonly as it is simple by comparing with other methods, but complex in execution and requires skills and expertise [10].
- Anil Gurses et al. (2020), introduced method for human identification using dental X-ray images, specifically panoramic X-rays. The method combined two techniques, Mask R-CNN (convolutional neural networks) and (Speeded Up Robust Features) SURF, to match dental images. It takes a tooth-by-tooth approach, comparing each tooth in the dental image separately. First, the teeth in the X-ray images are segmented and classified using Mask R-CNN. Then, using SURF key points are extracted from each tooth in the unidentified dental image and compared with those in a database of previously recorded dental images. The identification is made by combining the individual scores for each tooth. The Mask R-CNN method was tested on 8896 tooth images for segmentation and human identification with SURF is tested on 102 panoramic dental images from 51 people taken. The results showed 80.39% match rate [11].
- Qingsong Wu et al. (2021), presented an approach called the attention-based multi-supervision network (AMNet) for human identification using dental panoramic X-ray images. AMNet used an attention mechanism to create accurate attention masks that helped the model to focus on important parts of the image. It combined the features from multiple levels to capture global information and used part-specific features to focus on local details for better identification. The process extracted features from dental panoramic X-ray images and then compared them by calculating matching scores using cosine similarity. This score helped to determine if the images in the query and gallery come from the same person. The model is trained on dataset consists of 22,172 images from 9,490 subjects and tested on a set of 665 dental panoramic X-ray images from 503 different people, the method achieved a good performance [12].
- Fei Fan et al. (2020), developed DENT-net, an automated identification system based on a customized convolutional neural network (CNN). The system was trained using 15,369 panoramic dental radiographs (PDRs) from 6,300 individuals. Before training, the images were enhanced using affine transformation and histogram equalization to improve quality.

The performance of DENT-net was impressive and achieved 85.16% accuracy for identifying individuals using dental records, which can be particularly valuable in emergencies or forensic investigations [1].

- Yancun Lai et at. (2021) presented a method using deep convolutional neural networks (CNNs) for human identification through dental X-ray images. The method focused on automatically matching 2-D panoramic dental images. It combined convolutional neural networks with learnable connected attention modules to adaptively learn inter-layer connections. Test was performed on a dataset of 1,168 panoramic images from 503 people and achieved 87.21% accuracy for identification [13].
- Yi Lin et al. (2023), presented a approach for dental-based human identification (DHI), especially when there were not many samples available. The method used a combination of classifier and generator, which helped to generate best results. A generative adversarial network (GAN), called DHI-GAN, is created for this purpose. An attention block is added to help the model focus on both small details and big patterns and learned better features. This attention block is also applied to the classifier to improve identity-related information. The DHI-GAN model is achieved 92.5% accuracy. This approach helped reduce the need for many training samples [14].
- Jiafa Mao et al. (2023), introduced a method for identifying individuals based on features from dental impressions. The author started by proposing an adaptive object detection method using YOLOv8 to identify and segment tooth-prints. Then, a new geometric feature, called calibrated offset distance, is introduced along with the SIFT method to capture multi-scale and multi-dimensional features. These features are extracted from the overall tooth-print, smaller tooth-prints, and individual teeth. Finally, the extracted features are combined to improve the method's accuracy and robustness. The experimental results showed that the proposed approach performed well in identifying individuals [15]. Following table 1 shows the studies that have applied deep learning to dental x ray for human identification.

Table 1: The studies related to human identification using dental x ray with deep learning technique.

Authors	Deep learning architectures	Radiograph used	Metrics
Anil Gurses and Oktay (2020) [11]	Mask R-CNN and SURF	Panoramic X-rays	Accuracy - 80.39%
Sathya B, & Neelaveni, (2020) [16]	CNN and transfer learning	Panoramic X-rays	Accuracy for Molar- 97.5%, Premolar -94%, Canine- 94.5% and Incisor - 95%.
Fan F. et al.,(2020) [1]	CNN (DENT-net)	Panoramic X-rays	Rank-1 accuracy - 85.16% and Rank-5 accuracy - 97.74%

Authors	Deep learning architectures	Radiograph used	Metrics
Yancun Lai et at., (2021) [13]	CNN	Panoramic X-rays	Accuracy -87.21%
Qingsong Wu et al., (2021) [12]	AMNet	Panoramic X-rays	Rank-1 accuracy - 88.72% Rank-5 accuracy - 95.79%
Lin Y. et al., (2023)[14]	DHI-GAN model	Panoramic X-rays	Accuracy -92.5%

3. Research Gap

- Traditional human identification methods using dental X-rays highly rely on high-quality post-mortem (PM) images, which may be unavailable in real-world scenarios such as disaster victim identification.
- Existing approaches often lack an integrated framework capable of simultaneously improving image quality and performing identification, making it difficult to work with low-quality or incomplete PM X-rays efficiently.
- In the Indian context, the application of deep learning techniques for human identification using dental X-rays remains largely unexplored.

4. Problem Statement

To develop a framework using Generative Adversarial Networks (GANs) and deep learning embedding matching for human identification using panoramic dental X-rays, with a focus on matching degraded post-mortem (PM) X-rays to ante mortem (AM) X-rays.

5. Objectives of Study

- Analyze current literature on human identification using dental x ray with deep learning approach.
- Asses different deep learning approaches used for PM and AM x ray matching for human identification.
- To propose framework and methodology for human identification using dental x ray .
- Validate proposed framework of human identification by matching degraded PM x ray with AM x ray and improve accuracy of matching x ray

6. Research Hypotheses

- H1: GAN-based restoration techniques can enhance the quality of PM X-rays, that will enable better AM-PM matching.

- H2: A deep learning framework incorporating restored PM data will improve identification accuracy compared to existing methods.
- H3: The proposed approach is scalable and generalizable across diverse datasets and real-world scenarios.

7. Research Methodology

The research methodology for the proposed approach focuses on developing an innovative framework for human identification using panoramic dental X-rays, specifically it will target the matching of ante mortem (AM) and post-mortem (PM) X-rays. The methodology is structured into different phases explained below and shown in figure 4.

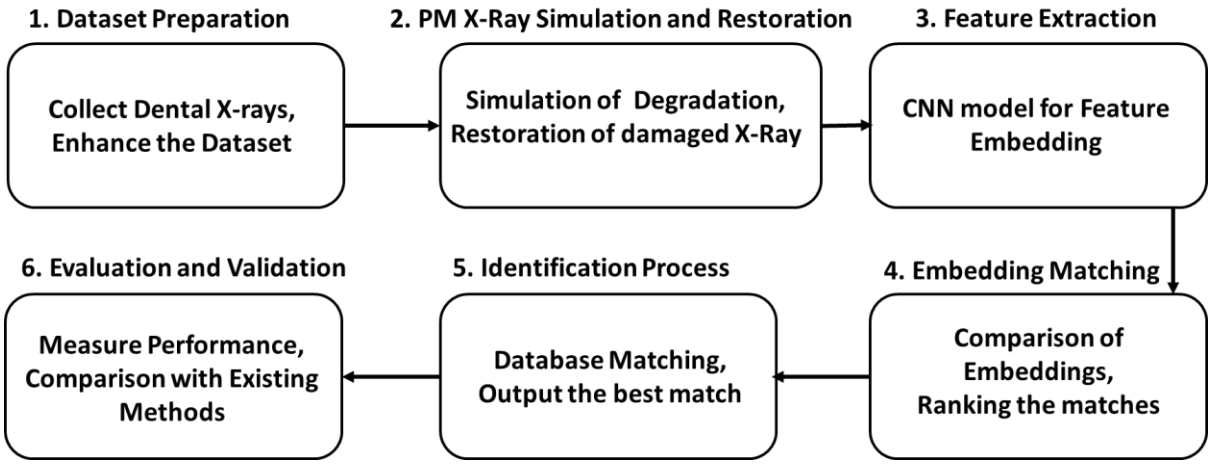
1. Dataset Preparation
Collect Dental X-rays, Enhance the Dataset
2. PM X-Ray Simulation and Restoration
Simulation of Degradation, Restoration of damaged X-Ray
3. Feature Extraction
CNN model for Feature Embedding
4. Embedding Matching
Comparison of Embeddings, Ranking the matches
5. Identification Process
Database Matching, Output the best match
6. Evaluation and Validation
Measure Performance, Comparison with Existing Methods

Figure 4: Phases in the methodology for human identification

Phase 1: Dataset Preparation

1. Data preparation:
    - Collect dataset of panoramic dental X-rays (AM X-rays) from a diverse set of individuals.
2. Data Augmentation:
    - Apply transformations such as rotation, scaling, noise addition, brightness changes, and slight blurring to artificially expand the dataset.
    - This step will generate multiple AM X-rays per individual.

Phase 2: PM X-Ray Simulation and Restoration (for Testing)

1. Simulated Degradation:
    - To simulate real-world scenarios, create degraded subset of AM X-rays, that will mimic damaged PM X-rays. Various degradation techniques will be applied to create dataset of degraded PM X-rays.
2. GAN-Based Restoration:
    - Train Generative Adversarial Networks (GANs) to restore damaged or degraded PM X-rays.

- The generator reconstructs missing features, while the discriminator ensures the restoration is realistic and retains key identity-related details.

Phase 3: Feature Extraction

1. CNN model for Feature Embedding:
   - Use CNN models to extract high-dimensional feature embedding from both AM and PM X-rays.
   - These embedding are high-dimensional representations of the X-rays, capturing discriminative features such as tooth contours, alignment, and structure.
2. Fine-Tuning CNNs:
   - Fine-tune models on the augmented AM X-ray dataset to adapt them specifically to dental X-ray characteristics.

Phase 4: Embedding Matching Using Similarity Metrics

1. Compare Embeddings:
   - Comparison of feature embedding of AM and PM X-rays using similarity metric.
   - With these try to minimize the distance between embedding of the same individual while maximizing the distance between embedding of different individuals.

Phase 5: Identification Process

1. Database Matching:
   - Compare the feature embedding of a given new PM X-ray against the embedding of all AM X-rays in the database.
   - Use a ranking mechanism to determine the closest match based on embedding similarity.
2. Output the best match:
   - Return the best-matched AM X-ray(s) along with a similarity score.

Phase 6: Evaluation and Validation

1. Performance Metrics:
   - Evaluate the performance of the system using evaluation metrics like accuracy**,** precision**,** recall**,** and F1-score to ensure robust performance and presented as follows.
   - Specific metrics like rank-1 accuracy and are used to assess identification quality.
2. Comparison with Existing Methods:
   - Compare the proposed approach performance against existing methods, to highlight improvements.

8. Statistical Plan

i) Metrics for Evaluation:

- Accuracy, precision, recall, F1-score, rank-1 accuracy

ii) Hypothesis Testing:

- Different tests will be performed to compare the performance of the proposed approach with existing methods.

iii) Cross-Validation:

- Perform k-fold cross-validation to ensure the robustness of the model.

9. Expected Outcomes of the Study

- A novel GAN-driven framework capable of restoring degraded PM X-rays and enhancing AM-PM matching accuracy.
- Improved identification performance compared to existing methods, particularly in low-quality data scenarios.
- A scalable and efficient approach for forensic odontology and disaster victim identification.

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